Nano Tech and the Military: National Threat or National Security?

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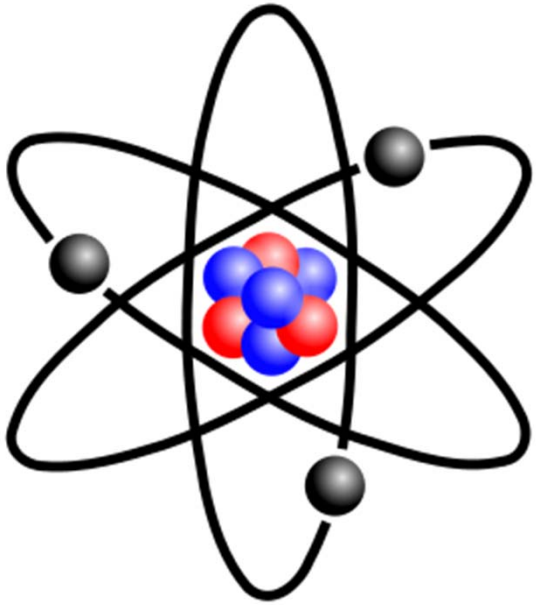
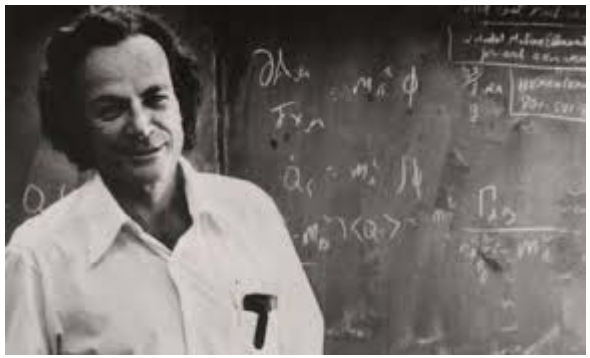
Agenda



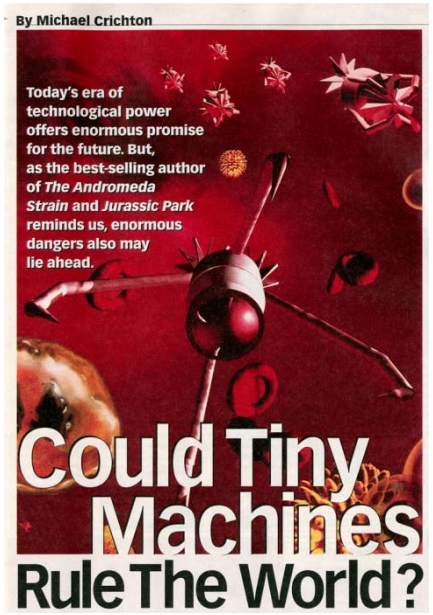
- Technical Overview of Nano
- National Security
  - Strategy and Policy
  - Instruments of National Power
  - Ethics
- The Future

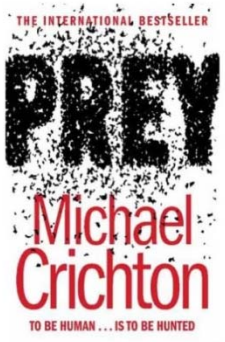


“There is plenty of room at the bottom.”

- Richard Feynman, 1959

Image: Richard-Feynman.net



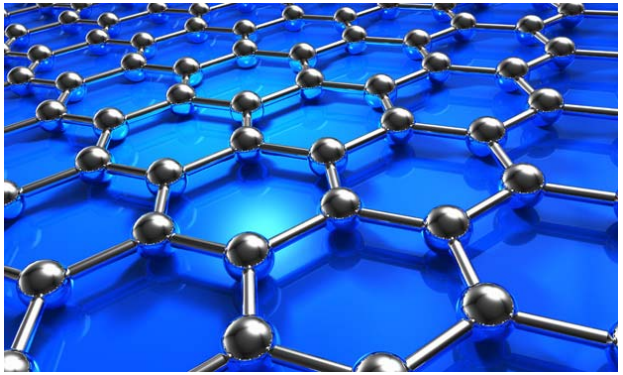


Michael Crichton's "PREY"

- Nanoparticle Robots escape from the lab
- Programmed as predators, swarming, replicating and evolving rapidly
- Terrorizing the world
- Possible today?

Images: Michaelcrichton.com

What is Nanotechnology?



- Nanoscience: the field of study concerning how matter behaves when it is configured on the nanometer scale.
- Nanoscience has fostered and enabled nanotechnology, which is the application of nanoscience
- Uses a common alphabet: The Periodic Table
- Uses a common grammar: Physics, Chemistry, Biochemistry, & Material Science

Image: Nanotechwizard.com

Critical Issues of Scale

The Macroscale

Small Ant	2,000,000 nm
Dust Mite	250,000 nm
Human Hair Diameter	100,000 nm
Talcum Grain	10,000 nm
Red Blood Cell	8,000 nm
E. Coli Bacterium	1,000 nm
Smallest Bacterium	200 nm
Influenza Virus	100 nm
Cellular membrane	10 nm
C_{60} Atom	1 nm
Francium Atom	.5 nm
Water Molecule	.3 nm
Oxygen Atom	.13 nm
Hydrogen Atom	.06 nm

The Mesoscale

The Nanoscale

Drawing by Donna Dulo, adapted from McCarthy (2003).

Critical Issues of Scale

The Macroscale

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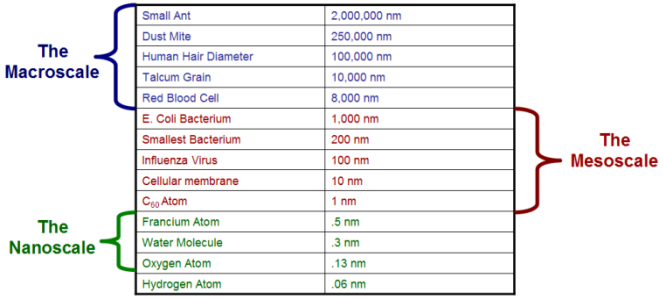
- The laws of physics are the same regardless of size
- Gravity, electromagnetism, and fluid dynamics have the same effect
- Classical equations apply universally and predictably
- Models can be predicted and proved experimentally with precision
- Examples:
  - Red blood cells follow the same fluid dynamics as the liquid methane flows on Saturn's moon Titan
  - Dropping a rock on Earth and Pluto follow the same laws of gravity

Critical Issues of Scale

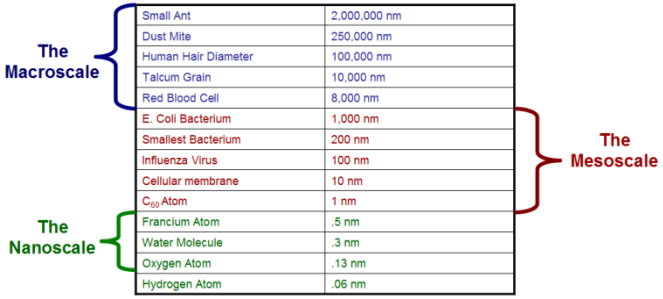
The Mesoscale



- The three orders of magnitude between the macro and nano scales
- Mysterious region where neither set of laws are accurate
- Quantum Field Theory becomes exponentially complicated as the number and size of particles increases
  - Random voids and impurities creep in
  - Quantum waveforms are disrupted in unpredictable ways
- Macroscale classical laws lose validity as the non-average behavior of individual particles stand out, eliminating statistical viability

Critical Issues of Scale

The Nanoscale



- The laws of macroscale physics barely apply
- Behavior of particles governed by quantum mechanics: “Quantum Field Theory”
- Particles really “probability waves” → regions where a particle like phenomenon is more or less likely to occur
- Small molecules possess a high degree of symmetry and a relatively small number of constituent particles
- Particle behavior under various circumstances can be predicted with great accuracy

Quantum Nano Issues

Degree of Complexity

100^0 100^1 100^2 100^3 100^4

Hydrogen — Niobium — Gallium Arsenide — Uranium Alloys — Cuprate Perovskites

Simple Atomic Physics

Superconductivity

Fractional Quantum Hall Effect

Heavy Electrons

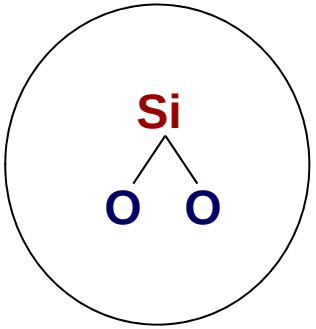
High Temp. Superconductivity

Emergent Phenomena

Drawing by Donna Dulo, adapted from McCarthy (2003).

Solid State Devices

Introduction to Solid State Devices

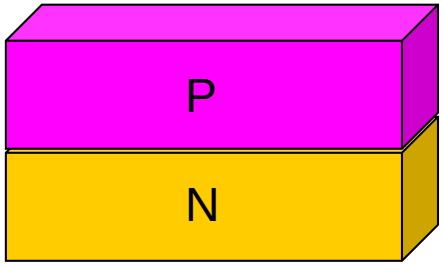


Native Oxide
of Silicon

- Semiconductors are insulators that conduct electrons within a narrow energy band
- Semiconductors require much higher voltage and temperature to conduct electricity
- The native oxide of silicon is most common semiconductor
- The amount of energy to get an electron from the valence band over the band gap to the conduction band varies
- This energy can be adjusted through doping: infiltrating other chemical compounds into the crystal lattice of the semiconductor

Drawing by Donna Dulo

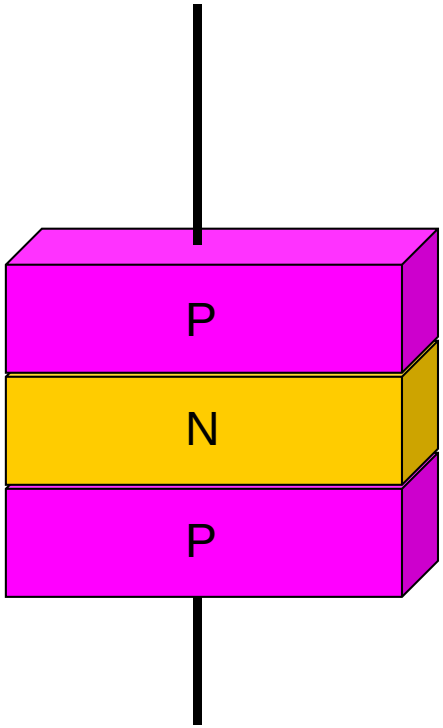
Solid State Devices



- N type “negative” doping uses phosphorous to donate excess electrons
- P type “positive” doping uses aluminum to produce holes to borrow electrons
- P-N layering creates an electron valve that allows one way electron traffic
- The foundation for transistors, diodes, LEDs, etc
- Almost all classical computing is built upon P-N junctions

Drawing by Donna Dulo

Quantum Nano Devices



Drawing by Donna Dulo

Quantum Wells

- Late 1980's discovery: add another layer to P-N junction: P-N-P (using gallium arsenide)
- Creates a "trap" that traps electrons in the middle layer and does not let them escape
- If N layer is made thin (10 nm) it approaches the upper limit of the nanoscale and strange things start to happen
- Along vertical axis of trap, electrons stop following regular laws of physics
- Positions and velocities become probabilistic in nature
- Electrons become waves rather than particles

Quantum Nano Devices

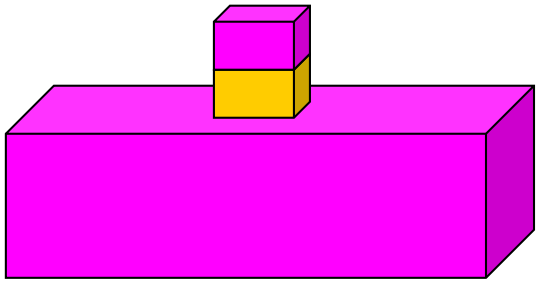
Quantum Wires

- Quantum wells, used for simple lasers and fiber optics, confines electrons to two dimensions
- If top 2 layers are stripped, electrons take a wave like behavior on third axis
- Produces more intense electron behavior
- Quantum wire lasers can produce in excess of 40 GHz of switching
- Acts as precision waveguides

Drawing by Donna Dulo

Quantum Nano Devices

Quantum Dots

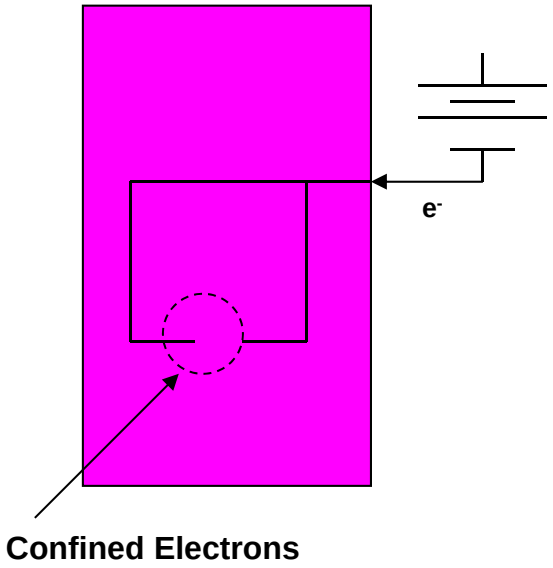


- Cutting a square out of the top 2 layers confines the electrons to three dimensions
- Unable to flow, electrons behave like de Broglie standing waves or probability density functions
- As waves, just like negative particles, repel each other and attempt to get as far away from each other as possible
- This arrangement mimics electrons in orbit in an atom, even though there is no “nucleus” in the dot

Drawing by Donna Dulo

Quantum Nano Devices

Electrostatic Quantum Dots

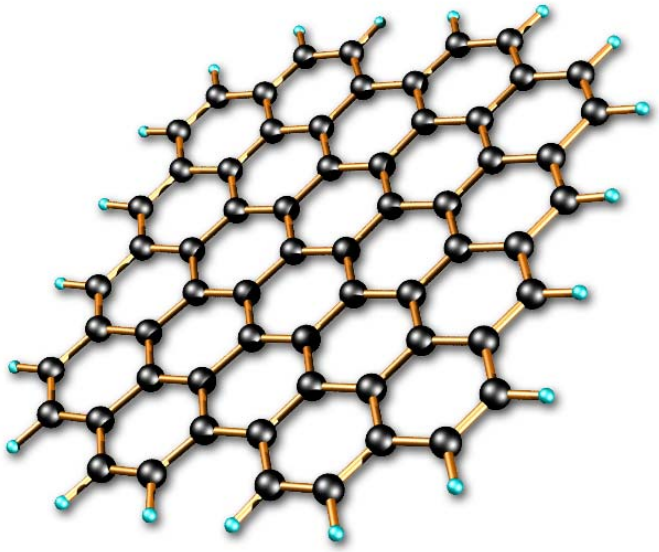


- Instead of slicing the semiconductor material, etched electrodes are arranged to confine the electrons
- A voltage confines the electrons in the quantum dot
- Can be adjusted to resemble any atom on the periodic table
- “Artificial Atom”
- Pump in electrons to match the periodic table

Drawing by Donna Dulo

Quantum Nano Devices

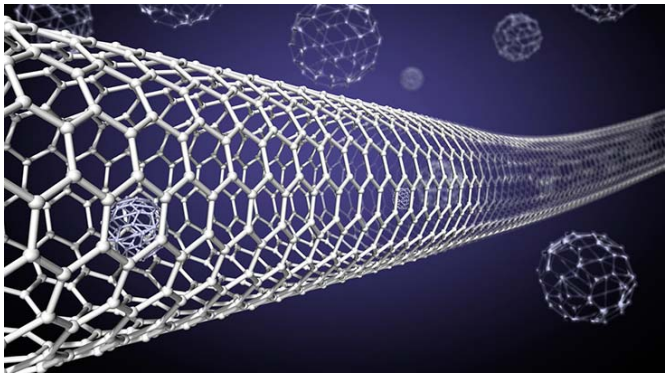
Graphene Quantum Dots



- A sheet of carbon atoms in a honeycomb pattern just one layer thick
- Exhibits quantum spin Hall effect
- Crystal has spin up and spin down characteristics of electrons
- Mysterious feature of quantum physics makes crashes impossible
- Channeling electrons for computational, communications, and energy purposes

Image: Nanotechwizard.com

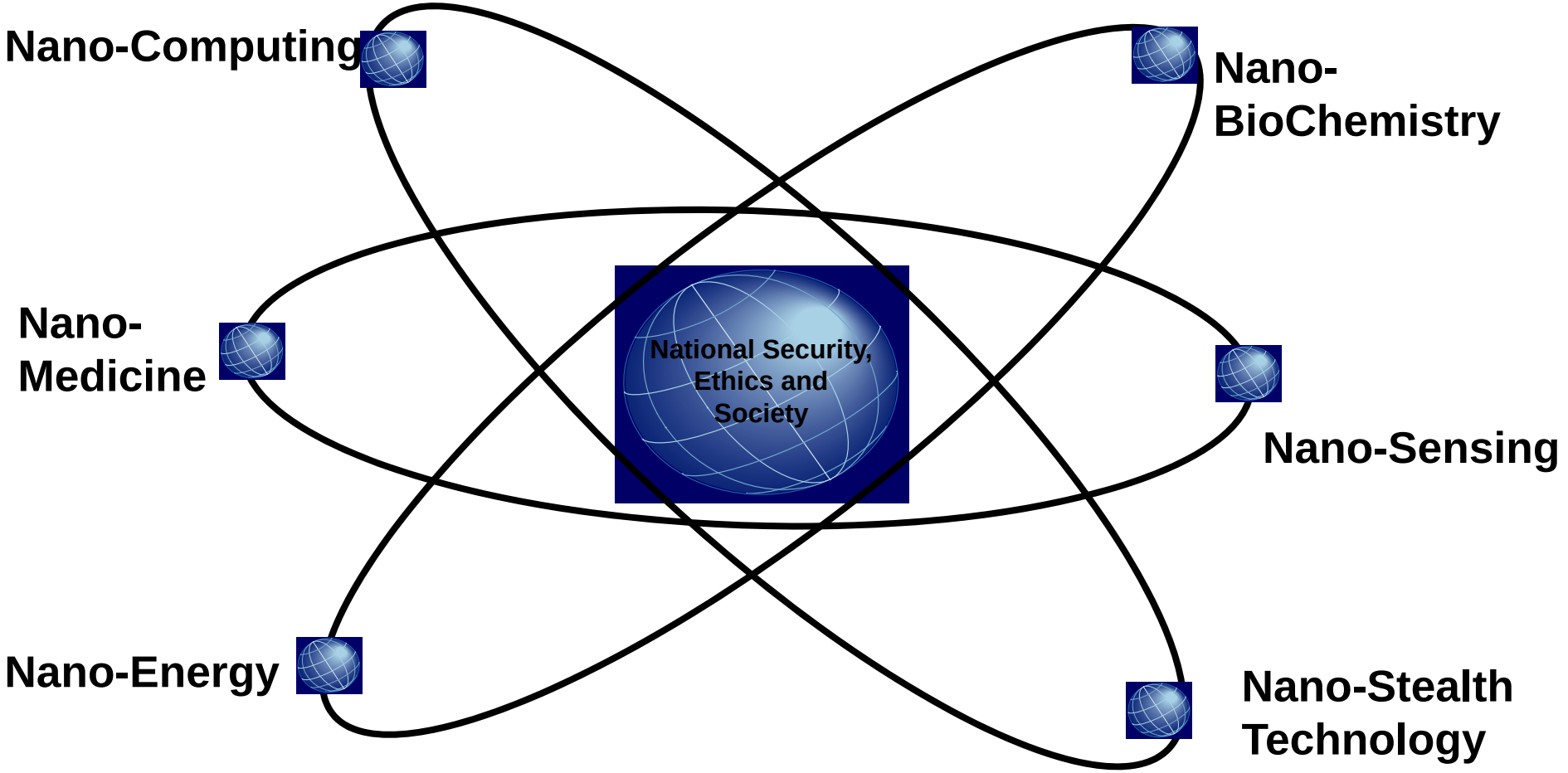
Nano Medicine Devices



- Carbon Nanotubes: a single atomic layer of carbon wrapped up into a tube: medical delivery system, drug delivery system, medical device delivery system (Example: stent)
- Gold Nanoparticles: can attach DNA to them, detect genetic mutations, can detect viruses and bacteria, can destroy disease, can act as internal sources of radiation
- Nano Proteins: Protein based nano-molecules act as catalysts of bio-chemical reactions and also as antibodies and cellular gatekeepers
- Bio-nano Sensors: detect disease and cancer

Image: aatitec.com

National Security Issues



National Security Issues

- Instruments of National Security
  - Military
  - Political
  - Economic
  - Information Technology
- Military and Information Technology can Leverage Nano Technology for the furtherance of National Security
- Nano Technology can be used offensively or defensively to further National Security
- Information Technology can be seen in this context as the instrument of cyber security, information assurance, and cyber war

National Security Issues

Levels of National Defense and Offense

Strategic

The command and control of the nation's armed forces in peacetime and in war. Uses of all instruments of national security. Protection of nation, civilian population, industry capacity, energy sources, national infrastructure.

Operational

The command and control of the nation's armed forces in peacetime and in war in theater specific areas of the world through theater specific operations. Fulfilment of theater specific objectives through the execution of local campaigns.

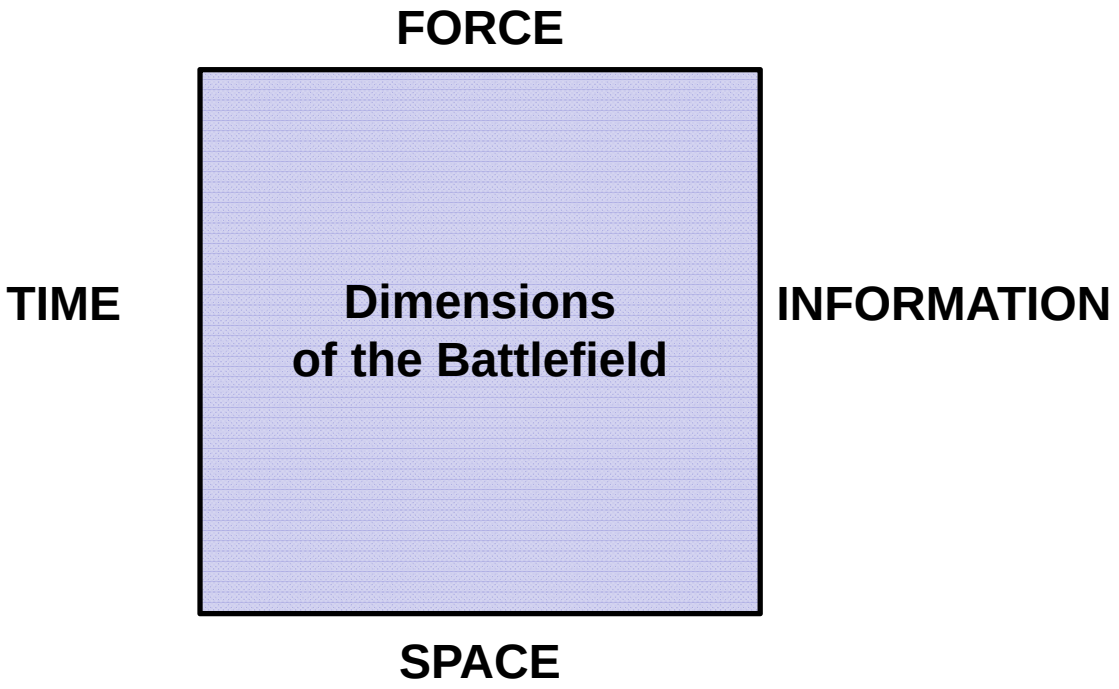
Tactical

The level where military force and action are undertaken to fulfil tactical objectives of the military strategy. Action is at the physical and cyber level of a specific combat zone or sector to destroy or neutralize the enemy or seize control of the sector.

Drawing by Donna Dulo

National Security Issues

Dimensions of the Battlefield



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National Security Issues

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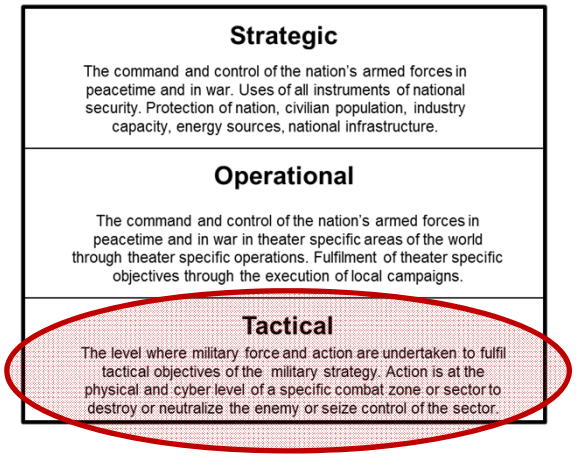
- Revolutionary technology always starts and the lower tactical levels and evolves into technology or operational and strategic significance
- Strong, viable technology causes a "Revolution in Military Affairs", essentially changing the way warfare is conducted
- Examples: the cannon, propeller driven ships, the submarine, aviation, satellite technology, nuclear bombs, drones
- Is Nano Technology next after drone technology?

Drawing by Donna Dulo

National Security Issues

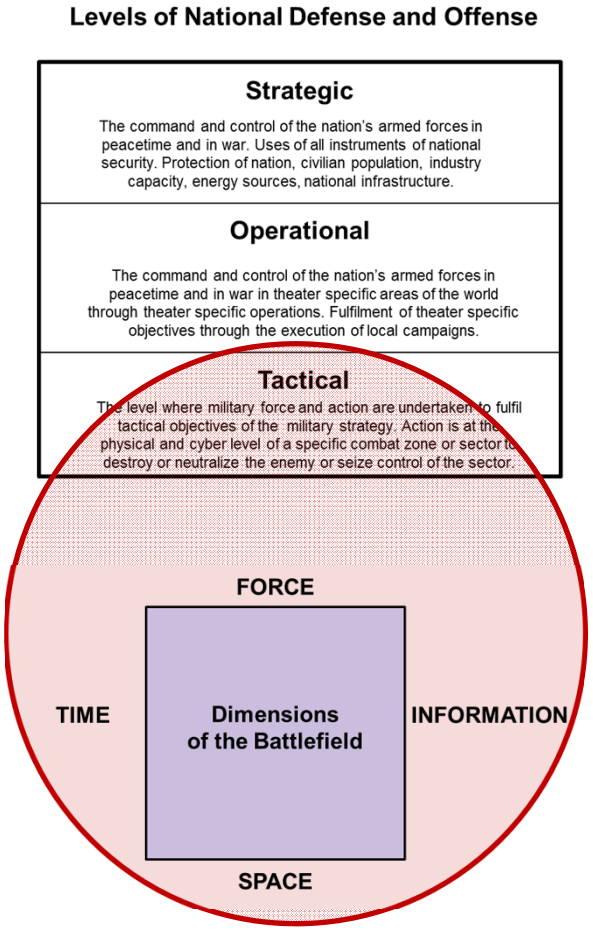
Levels of National Defense and Offense



- All uses of Nano Technology will start at lower local tactical levels
- Test implementations in specific regions with a specific national security purpose
- Effects will be studied by the military industrial complex and related academic institutions
- Initial uses will be highly classified
- Initial uses will be conducted by specialized military units such as special forces

Drawing by Donna Dulo

National Security Issues

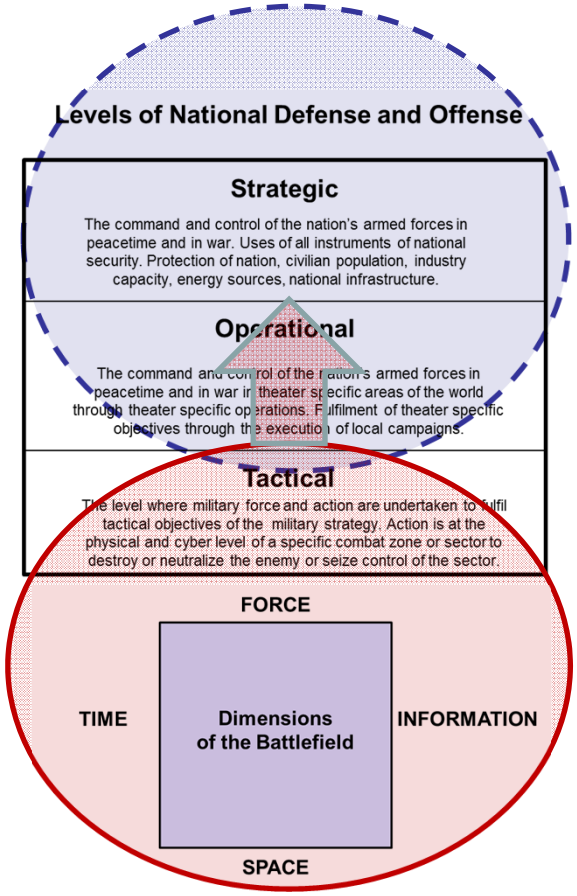


Current & Near Future Applications

- Effective use of Nano Technology must occur at the lower tactical levels and leverage the dimensions of the battlefield to improve them
- If battlefield dimensions are not significantly improved by a technology, the technology may not be viable in the long term
- Improvements in soldier and sailor battlefield mortality rates can be considered an improvement in the “Forces” dimension
- Revolutionary technologies improve several battlefield dimensions

Drawings by Donna Dulo

National Security Issues



- As technology becomes perfected, it will evolve into uses at higher levels of national security
- May become the basis of national policy
- At this point the use will become public
- Other countries and nation states will try to develop the technology as well as counters to it
- International bodies such as the UN will begin to regulate its use
- May lead to an international Revolution in Military Affairs

Drawing by Donna Dulo

National Security Issues

Current & Future Uses of Military Nano Technology

- Smart Quantum Dots: tether-less sensors to monitor the enemy (Intelligence, Surveillance, and Reconnaissance)
- Remote Photographic Motes: Intelligence imaging
- Cloaks of Invisibility: Nano Metamaterials with light and microwave dispersion properties that wrap objects to ensure that radiation waves pass around and recombine behind the object with little or no radiation absorption
- Nano-Bio-Chemical devices to disperse biological and chemical weapons or to provide antidotes against them
- Ad Hoc Nano-Computer networks to move information

National Security Issues

Current & Future Uses of Military Nano Technology

- Quantum computing to significantly improve military computation, weapon system precision
- Cyber security and warfare computational improvements
- Improved battlefield energy distribution
- Improved battlefield communications
- Improved battlefield medicine, diagnosis and treatment
- Nano Weapons (Large and Small Scale), Nano-Bombs, Nano Thermite weapons
- Nano Weapons of Mass Destruction

Ethics

- **Environmental Issues**
  - Intentional or Unintentional Release of Nano Materials
  - Do materials decompose or remain chemically stable?
  - Are the materials taken up into the ecosystem causing damage
  - How extensive will the damage be?
  - Have studies been done and risk calculated?

- **National Power**
  - How far will a nations power extend?
  - Will the technology be exploited for imperial expansion and dominance?

- **Exploitation**
  - What if the technology gets in the hands of belligerent nation states or terrorists?
  - Misuse by the enemy that doesn't follow Geneva Convention

Ethics

- **Testing & Risk Management**
  - What is the extend of nano technology testing for battlefield use?
  - How much risk must be assumed?
  - Should military lives be a dimension of risk?
  - Environmental risk?
  - What are the long term effects of the technology?
- **Law & Regulations**
  - How extensive should national laws and regulations be before military implementation?
- **Societal Impacts**
  - What are the social and psychological impacts on the national population if nano technology is used for military purposes?
  - Dissent in the population?

Ethics

- **Impacts on Humanity**
  - Adverse impacts on enemy population (medical and psychological)
  - Impacts on world order (Order or Chaos)
  - Impacts on military personnel
  - Societal impacts

- **Relation to Other Sciences**
  - Nano technology use has similar ethics to other technologies:
    - Process Chemistry
    - Bio-Technology
    - Material Sciences
  - What are the differences?
  - Can the differences evolve into new ethical platforms?

Ethical Frameworks

- Nano technology military ethical frameworks must revolve around the use/impact of the technology
- Must be humanity centric
- Must be environmentally centric
- Must enforce proper and extensive risk management, technology testing and evaluation
- Must be developed at the national level and encoded into law before the technology is used
- Must include methods for studies of deployments so that laws may be improved and adapted to evolving technological implications

Conclusion

- Nano technology is on the horizon and will become a major force in military operations as an instrument of national power
- Nano technology may force a Revolution in Military Affairs if the technology is well developed, tested, and implemented thus improving the dimensions of the battlefield
- Nano technology must be implemented along with comprehensive ethical frameworks and corresponding regulatory schemes and laws
- Nano technology has the potential for mass destruction, so ethics is a vital concern
- National strategy must drive the use of nano technology, never the other way around

The Future

In his 1962 collection *Profiles of the Future*, Sir Arthur C. Clarke formalized three “laws” of technological development:

First Law: “When a distinguished but elderly scientist states that something is possible, he is almost certainly right. When he states that something is impossible, he probably wrong.”

Second Law: “The only way of discovering the limits of the possible is to venture a little way past them into the impossible.”

Third Law: “Any sufficiently advanced technology is indistinguishable from magic.”


Questions?

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